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VERTICILLIUM WILT OF POTATO IN RELATION TO FUNGICIDES ADDED TO THE FERTILIZER[1]

DONALD FOLSOM[2]

INTRODUCTION

Up to the present, all but one of the *Verticillium* cultures isolated by the author from stems or tubers of wilt-infected plants grown in Maine have been of the *albo-atrum* type, with no microsclerotia. However, the fungus can overwinter in the soil in some way. An example is given in table 1, which gives the history of a field in central Maine as observed by the author from 1945 to 1956 inclusive. After 5 years with no difference between one part of the field and another with respect to kind of crop, potatoes were grown on one part and clover on the other. The potatoes showed wilt, according to the owner. In the following year a healthy potato seed stock was planted on both parts. Where it followed potatoes, practically all the potato hills had Verticillium wilt, whereas there was no wilt following clover. The owner of the field, like others who have found themselves in a similar situation, wanted a remedy and preferred a practical chemical treatment to crop rotation.

The field in question eventually showed (Table 1) that four years between potato crops were enough to eliminate soil infestation. Other Maine fields have shown that three years in oats are enough, and that even only two years in oats and clover are enough or nearly enough. However, some farmers are not inclined to keep land out of potatoes more than one or two years, and would like a preventive or quick cure in the form of a chemical treatment.

The use of fungicides mixed with the fertilizer seemed to be a very practicable method and the possibility of its effectiveness was indicated by some research workers (1, 3, 4).

TABLE 1.—*History of a field in central Maine.*

Year	North Part	South Part
1945	Potatoes	Potatoes
1946	Potatoes	Potatoes
1947	Oats	Oats
1948	Potatoes	Potatoes
1949	Oats	Oats
1950	Potatoes	Clover
1951*	Potatoes, 98 per cent *Verticillium* wilt	Potatoes with no wilt
1952	Oats	Oats
1953	Clover	Clover
1954	Hay	Hay
1955	Hay	Hay
1956	Potatoes with no wilt	Potatoes with no wilt

*Same seed stock planted in both parts.

[1]Accepted for publication October 16, 1956.
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In 1953 about 25 per cent of the hills showed Verticillium wilt in a field on Highmoor Farm (a Maine Agricultural Experiment Station farm) in southwestern Maine. This field was used in 1954 for a test of the effects, on wilt, of several fungicides mixed with the fertilizer. During the winter of 1953-54 preliminary tests were made in the greenhouse at Orono, Maine.

Greenhouse Tests

Potato plants of the Kennebec variety were grown in the greenhouse. Sandy loam was placed in 3x3x3-inch bottomless veneer boxes in 15x15x2-inch flats and the whole was steam-sterilized. The seed tubers were of the 1953 crop and were ready to germinate. Each seed-piece, one per box, contained one eye and weighed about a gram. Planting was done on January 20, 1954, and the small size of the seed-piece (and possibly other factors) limited the size of plant to an average height of 5.6 inches in untreated controls.

Commercial 7-7-7-2 fertilizer was mixed into the top part of the soil at the rate of 1.3 grams per box or, based on surface area, at a ton per acre. This is more nitrogen than is usually used in commercial practice in Maine, but Roberts (5, 6) had reported that an increase in N increased tomato Verticillium wilt. The fertilizer contained an admixture of fungicide. The following fungicides were tested.

Dithane Z-78 (65 per cent zineb)
Fermate (76 per cent ferbam)
Phygon (50 per cent dichlone)
Thilate (pellets, 75 per cent thiram)
Orthocide (50 per cent captan)
Vancide 51W (containing zinc salts of dimethyl dithiocarbamic acid and 2-mercaptobenzothiazole)
HD-160 (experimental material from Rohm and Haas; sodium salt of 2-carboxymethylmercaptobenzothiazole (2, p. 22)
Calcium sulfamate

Each fungicide was used in one flat at five progressively decreasing rates arbitrarily designated as A, B, C, D, and N, N indicating none (untreated control). The rates varied with the fungicide and depended upon advice in letters and the literature, except that the maximum rate was intended to be high enough to be toxic or to be beyond economic practicability. Each rate was used on five plants and the 25 plants in each flat were arranged in a Latin square.

The fungus was cultured on a mixture of sandy loam and corn meal (3 per cent, as recommended by Roberts (6)) in glass jars. The infested medium was applied to the soil in the filled flats which had been freshly steamed in them. After time had been given for the fungus to infest the soil in a flat, a 25-box fungicide series was set on the infested soil into which roots of the young plants grew.

Plant height on April 12 varied with the fungicide (Table 2) and with the rate of application of the fungicides (Table 3). HD-160 reduced growth greatly at the higher rates, as shown in figure 1, whereas Dithane and Phygon increased growth at the lowest rate. Orthocide burned the leaf

TABLE 2.—*Some effects of fungicide on potato plants in the greenhouse.*

Fungicide			Plants		
Kind	Mgs. per Box	Lbs. per Acre	Height In.*	Breakdown Per cent	Verticillium Wilt Per cent
Dithane	10-2000	15-3080	6.6-8.0	40	25
Fermate	10-2000	15-3080	4.0-6.0	10	20
Phygon	10-1000	15-1540	5.4-5.8	40	15
Thilate	50-1000	77-1540	3.4-5.4	0	15
Orthocide	10-1000	15-1540	4.8-5.8	0	15
Vancide	10-1000	15-1540	3.6-5.0	30	15
HD-160	10-1000	15-1540	0.5-3-6	0	0
Calcium sulfamate	10-100	15-154	3.0-5.4	0	5
None (control flat)	..	..	4.3	20	12

*Range of averages for series receiving different fungicide rates.

TABLE 3.—*Some effects of different rates of fungicide application on potato plants in the greenhouse.*

Series	Fungicide Rate		Plants	
	Mgs. per Box	Lbs. per Acre	Height In.	Verticillium Wilt Per cent
A	100-2000	154-3080	4.4	2.5
B	30-1000	46-1540	4.6	7.5
C	20-200	31-308	4.6	20.0
D	10-50	15-77	5.4	25.0
N	0	0	5.6	32.5

blades of all treated plants by April 5 and even of the untreated plants (in the same flat) by April 12. A breakdown characterized by leaf abscission and by brown blotches and streaks in the cortex and pith of the stem, as shown in figure 1, occurred in some flats (Table 2). When left in a damp chamber, breakdown stems showed no fungous growth.

If a plant showed typical Verticillium wilt symptoms in the leaves, the lower part of the stem was removed and kept in a glassine envelope in a damp chamber until fungous growth developed which was examined microscopically. The wilt percentage was 12 in the control flat and varied from 0 to 25 with different fungicides as revealed in table 2. Wilt percentage was 32.5 per cent in the untreated control plants of the fungicide treated flats and, in general, decreased with the higher rate of fungicide (Table 3).

The greenhouse experiments with potatoes were duplicated with tomatoes of the Bonny Best variety, which were used by Wilhelm (7) to test the presence of *Verticillium albo-atrum* in soil. The tomato plants like the potato plants grew taller when treated with Dithane, but were different in that they showed no burning by Orthocide, no breakdown, no severe stunting by HD-160, and no wilt symptoms.

FIGURE 1.—Kennebec potato plants grown from 1-gram seed pieces in 3x3x3 inch boxes in greenhouse. Left to right, respectively, with 15 lbs. Thilate, 15 lbs. Phygon, and 60 lbs. HD-160 per acre applied in fertilizer, and showing normal growth, breakdown, and dwarfing.

During the winter of 1954-1955, a test with infested field soil showed less wilt (18 per cent) in potato plants grown in wooden veneer boxes than in plants grown in nutrient-treated black paper boxes ("Vitabands"), where there was 58 per cent. Plants in wooden boxes showed wilt in 30, 52, and 68 per cent, respectively, when infection came from soil cultures, comminuted agar cultures, and comminuted infected stems from the field, added to the flatfuls of steam-sterilized soil.

FIELD TESTS

Most of the chemicals tested in the greenhouse in 1953-1954 were tested in 1954 in a field of potatoes of the Kennebec variety. In this field in 1953, with very little wilt resulting from perpetuation in or on the Kennebec seed stock, the percentage of Verticillium wilt was 27 per cent in sandy soil, 24 per cent in clay soil, and 22 per cent in sandy loam. Nearly wilt-free seed was planted in 1954 in 100-foot single-row plots. The chemicals were hand-mixed with 8-16-16-2 fertilizer which was applied with a standard potato planter. The rate of fungicide was 20 or 100 pounds per acre. At both rates HD-160 stunted the plants to the same size as in control plots receiving no fertilizer. No other chemical had any apparent effect on vine growth. The Verticillium wilt percentages are given in Table 4. No two means were significantly different one from the other. Except for HD-160, generally the control plots showed less wilt than the plots receiving fungicides in the fertilizer. In general the results were not promising for the chemicals that were tested.

SUMMARY

Although two to four years in other crops can eliminate danger to potatoes from field-infestation by microsclerotia-free *Verticillium albo-*

atrum in Maine, such a rotation is too long for many potato growers and they would prefer a quick chemical method of control if it were practical. Certain fungicides were tested, as fertilizer admixtures, with respect to plant growth and Verticillium wilt. In the greenhouse the results with potatoes were much different from those with tomatoes. With potatoes the results in the field were very different from those in the greenhouse. The field results were not promising for the several chemicals that were tested.

TABLE 4.—*Effect on wilt of fungicides in the field.*

Fungicide	No. of Plots	Wilt (Per cent)
Vancide	14	24.1 ± 3.6
Thilate	14	22.1 ± 2.4
Dithane	14	21.4 ± 2.2
Phygon	14	21.1 ± 2.5
None (sandy loam)	12	21.1 ± 2.1
Fermate	14	18.5 ± 1.6
None (sandy soil)	21	16.6 ± 2.0
None (clay soil)	15	15.8 ± 1.8
HD-160	14	14.4 ± 1.8

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THE OCCURRENCE OF THE BROWNSPOT STRAIN OF POTATO VIRUS X[1]

A. J. HANSEN[2] AND R. H. LARSON[3]

A brownspot strain of potato virus X (necrotic spot—local lesion type), isolated from naturally-infected American varieties Warba and Chippewa, has been described by Ladeburg *et al.* (1) and Larson *et al.* (2). This strain differs from the commonly-known virus X strains in that dark brown localized lesions are formed on the inoculated leaves of *Nicotiana rustica* L.,[4] (Figure 1) and complete breakdown follows systemic infection of *Datura tatula* L. On *N. rustica* the lesions expand slowly along the veins as shown in figure 2 but the virus does not become systemic. On *Nicotiana tabacum* L. var. *Samsun*, the lesions on the inoculated leaves incited by the brownspot strain are slightly more purple than those caused by the ringspot strains. Lesions produced on the inoculated leaves of *Nicotiana glutinosa* L. also closely resemble those caused by the ringspot strain, being only slightly darker. The brownspot strain becomes systemic on both *Samsun* tobacco and *N. glutinosa* and can easily be overlooked in a mixture of strains.

The purpose of the study was to determine the occurrence of the brownspot strain of virus X in American and European potato varieties. Stock seed tubers of the varieties tested were obtained from the Potato Introduction Station, Sturgeon Bay, Wisconsin, and from Starks Farms Inc., Rhinelander, Wisconsin.

Three eye seed pieces from each of three sprouted tubers of each variety to be tested were propagated in 3-inch pots in the greenhouse, at 18-20° C. under normal light conditions, until they reached a height of about 15-20 cm. Two mature leaves of *Gomphrena globosa* L. and not less than three mature leaves of *N. rustica* were inoculated with a mixture of raw juice extracted from leaves of the three potato plants of each of the varieties tested. Carborundum (600 mesh) was used as an abrasive.

Brown necrotic local lesions appearing on the inoculated *N. rustica* leaves (Fig. 3) after 8-14 days at 24° C. were isolated by means of the single lesion method (1) and transferred to other *N. rustica* plants. Single lesion isolations were continued when necessary and supplemented by inoculation to *D. tatula*. On inoculation three sources of *N. rustica*[4] showed very slight differences in lesion type. The Wisconsin source of *N. rustica* was used throughout the remainder of this study. All experiments were carried out between March and May, 1956.

The brownspot strain of virus X was isolated, after one or more single lesion transfers, from 16 out of 51 potato varieties as shown in table 1.

[1]Accepted for publication October 23, 1956.

[2]University of Wisconsin, Department of Plant Pathology; on leave of absence from Max Planck Institut fur Zuchtungsforschung, Koln-Vogelsang, German Federal Republic.

[3]University of Wisconsin, Department of Plant Pathology, and Horticultural Crops Research Branch, ARS, USDA, Madison, Wis.

[4]The *N. rustica* seed was obtained from the following sources:

1. University of Wisconsin, Department of Plant Pathology
2. Max Planck Institut fur Zuchtungsforschung, Germany
3. Tabakforschunginstitut, Forchheim, Germany.

FIGURE 1.—Symptoms of the brownspot strain after 14 days on *N. rustica*. This culture was derived from the variety "Jubel" after three single lesion transfers.

FIGURE 2.—Expanding lesions of the brownspot isolate on the inoculated leaf of *N. rustica* after 21 days.

FIGURE 3.—Symptoms produced on *N. rustica* by a potato virus X mixture from plants of the German variety "Jubel". Note ring and brownspot lesions.

There was considerable variation regarding the size and number of the brownspot lesions appearing on *N. rustica* after the first raw juice mass transfer from different varieties. The first juice transfer from the varieties Houma, Kerrs Pink, Up to Date and Jubel to *N. rustica* resulted in 10 or more large brownspot type lesions per leaf as revealed in figure 3. On testing other varieties two or more single lesion transfers were made in order to increase sufficiently the number of lesions on *N. rustica*, Figure 1. In some cases it was difficult to identify the small necrotic lesions on *N. rustica* as the brownspot strain; therefore, supplementary inoculations were made to *D. tatula*. Isolations from the varieties Epicure, Green Mountain, Sebago and Warba produced few small-type lesions even after three or four single-lesion transfers on *N. rustica*. These were classified as the brownspot strain because of non-systemic reaction of *N. rustica*, systemic lethal necrotic reaction of *D. tatula* and local lesion reaction of *G. globosa*.

Since only one sample per variety was tested in the present studies, our results are far from complete. Other samples of the varieties that

reacted negatively may carry the brownspot strain of virus X, the occurrence of which seems to be more common than formerly recognized.

TABLE 1.—*Potato varieties harboring the brownspot strain of virus X.*

Variety	Origin	Source[1]
Jubel	Germany	1
Olympia	"	1
Arran Pilot	Great Britain	1
Epicure	"	1
Home Guard	"	1
Kerrs Pink	"	1
Up to Date	"	1
Chippewa	United States	2
Green Mountain	"	2
Houma	"	2
Katahdin	"	2
Kennebec	"	2
Russet Rural	"	2
Sebago	"	2
Triumph	"	2
Warba	"	2

[1]1. Potato Introduction Station, Sturgeon Bay, Wisconsin
2. Starks Farm, Inc., Rhinelander, Wisconsin

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A SURVEY OF APHIDS INFESTING POTATOES IN THE PLAINS OF WEST BENGAL[1]

H. C. CHOUDHURI

Since the discovery by Schultz and Folsom (14) and Murphy (13) that potato viruses are transmitted by aphids intensive surveys have been made on aphid populations by Davies (6, 7) and Broadbent (3, 4) with a view to obtain some knowledge of the distribution of potato aphids in different areas for growing of certified high-grade seed potatoes. The study of the incidence of these insect vectors for the transmission of viruses, which develop in such a high degree in potatoes, could hardly be over emphasized. The species that has been found to be most closely associated with virus transmission in the potato crop in this country is *Myzus persicae* Sulz., according to Banerjee and Basu (1). Although the importance of *Myzus persicae* Sulz., is well known, yet very little attention has been paid to it in India. Consequently very meagre information is available as to the incidence of aphids infesting the potato crop.

The potato growing tracts in the plains of West Bengal lie between 34 feet and 98 feet above mean sea-level. The mean annual rainfall ranges from 56 to 60 inches and the average rainfall and temperature during the potato growing season varies from 1.55 to 2.09 inches and 61.5° to 85.1° F. respectively (Figures 1 and 2).

Of the seed potatoes used in the plains about 30 per cent are usually imported from the hills where they are grown at altitudes of 5,000 feet to 8,000 feet and the rest of the seeds are produced in the plains.

AREA SURVEYED

Although potatoes are grown to a certain extent throughout the country the main bulk of the acreages are concentrated in the districts of Hooghly and Burdwan which contribute 29.3 and 18.9 per cent respectively of the total acreage of the state. In view of the importance of these two districts towards the states' supply of potatoes, a survey was carried out in these two areas where the farmers secure a substantial portion of their seed requirement from the stock grown in the plains. In the district of Hooghly the main centers of study were at Haripal and Tarakeswar whereas in the district of Burdwan these centers were at Kalna, Memari and Burdwan.

MATERIAL AND METHODS

The aphid considered was *Myzus persicae* Sulz. One hundred fields of potatoes were visited at intervals of 1-2 weeks from the beginning of January to mid-March although the record of the incidence of aphids was made until the end of February. The fields were scattered over the whole areas where the potatoes are largely cultivated.

The distribution of aphids in the potato crop was studied and

[1]Accepted for publication July 9, 1956.

[2]Special Officer, Potato and Crop Research, Directorate of Agriculture, West Bengal, Calcutta, India.

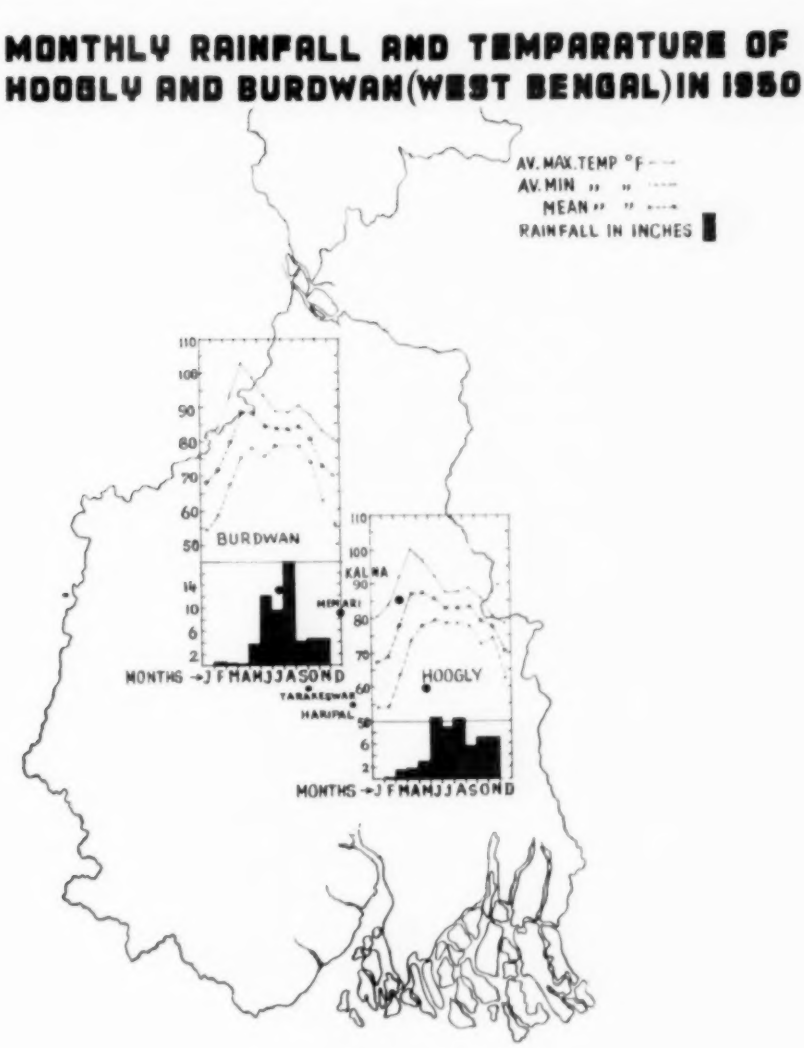
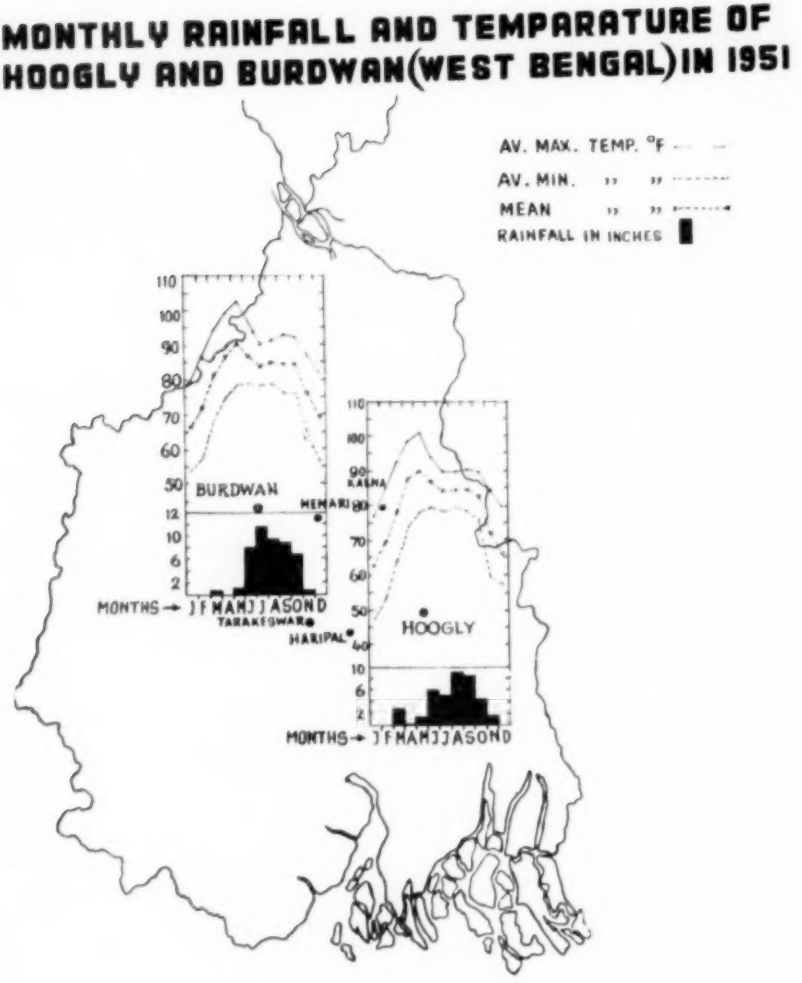

MONTHLY RAINFALL AND TEMPARATURE OF HOOGLY AND BURDWAN(WEST BENGAL)IN 1950
AV. MAX. TEMP °F
AV. MIN „ „
MEAN „ „
RAINFALL IN INCHES
BURDWAN
MONTHS → J F M A M J J A S O N D
KALNA
MEMARI
HOOGLY
TARAKESWAR
HARIPAL
MONTHS → J F M A M J J A S O N D

FIGURE 1.—Map of West Bengal showing areas surveyed and their meteorological conditions for 1950.

the number per leaf and per plant was calculated according to the method suggested by Broadbent (4). Counts of aphids were made throughout the season on the Darjeeling red round variety. To obtain a better estimate of the number of aphids per leaf and per plant, one hundred


MONTHLY RAINFALL AND TEMPARATURE OF HOOGLY AND BURDWAN(WEST BENGAL)IN 1951
AV. MAX. TEMP. °F
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RAINFALL IN INCHES
BURDWAN
MEMARI
MONTHS → J F M A M J J A S O N D
TARAKESWAR
HARIPAL
HOOGLY
KALNA
MONTHS → J F M A M J J A S O N D

FIGURE 2.—Map of West Bengal showing areas surveyed and their meteorological conditions for 1951.

random plants were taken instead of forty plants. From each of the hundred random plants selected, one upper, one middle and one lower leaf was examined taking approximately the same number of small, medium, and large leaves.

Experimental Data

Aphid Survey in 1950

In the plains the potatoes are planted from mid-October to November. The plants are not of fairly good height until January. Normally the migration of aphids to potatoes in the plains of West Bengal is from the end of December to January and they continue to move from plant to plant until February. In March the crop matures and aphid infestation falls.

Tables 1 and 2 show the incidence of aphids per leaf and per plant during different periods of January and February. It may be seen from table 1 that during the latter part of January, 1950, there was a sharp fall in the aphid population per leaf. This decrease of aphid movement is presumably due to the unfavorable climatic conditions in the early part of January. Davies (6) considered that the reduction or delayed arrival of aphids at the normal peak period was because of unfavorable weather conditions. It has been shown by Broadbent (4) that voluntary aphid movement can take place on windy days but the number of occasions when conditions in the crop are suitable for take-off decreased as the wind-speed increased and this accounts for the occurrence of fewer aphids in the air on windy days.

Further, during the whole of February, 1950, the aphid movement continued and increased and then decreased with the maturity of the crop. Broadbent (3) reported reduction of aphid infestation after July-August dispersal in north west Derbyshire. This drop of aphid infestation at the maturity of the crop is presumably due to the activity of predators and parasites.

Aphid Survey in 1951

Tables 3 and 4 show the incidence of aphids per leaf and per plant in different periods of January and February 1951. The migration of aphids was delayed in January but with the increase of temperature the aphid infestation per leaf increased until the maturation of the crop.

Broadbent (4) observed that the main migration of aphids, *Myzus persicae* Sulz., to potatoes in North Wales was in early June and they continued to move from plant to plant for about a month. During the dry hot summer the aphid population increased rapidly.

Spread of Disease in 1950

During 1950 the spread of crinkle and leaf roll viruses was studied. Table 5 and Figure 3 show the spread of the viruses and their relationship to the infestation of aphids. It is seen that there is no close correlation between the spread of virus diseases and maximum infestation of *Myzus persicae*. Broadbent and Gregory (5) reported similar results of the absence of a close correlation between the spread of rugose mosaic or leafroll and the maximum number of *Myzus persicae*, on the trap or on the plants.

TABLE 1.—*Showing the incidence of aphids per leaf and per plant during January, 1950.*

Location of Area	Aphids	First Fortnight of January			Aphids per Plant	Second Fortnight of January			Aphids per Plant
		On 100				On 100			
		Upper Leaves	Middle Leaves	Lower Leaves		Upper Leaves	Middle Leaves	Lower Leaves	
Haripal	Total number of aphids	81	101	193	166.05	7	9	32	19.84
	Aphids per leaf	0.81	1.01	1.93		0.07	0.09	0.32	
Tarakeswar	Total number of aphids	29	95	395	201.17	6	10	19	15.13
	Aphids per leaf	0.29	0.95	3.95		0.06	0.1	0.19	
Kalna	Total number of aphids	55	144	341	221.68	20	34	45	44.33
	Aphids per leaf	0.55	1.44	3.41		0.2	0.34	0.45	
Memari	Total number of aphids	45	86	161	125.12	5	13	25	18.01
	Aphids per leaf	0.45	0.86	1.61		0.05	0.13	0.25	
Burdwan	Total number of aphids	102	140	176	192.71	6	11	23	17.00
	Aphids per leaf	1.02	1.4	1.79		0.06	0.11	0.23	

TABLE 2.—*Showing the incidence of aphids per leaf and per plant during February, 1950.*

Location of Area	Aphids	First Fortnight of February			Aphids per Plant	Second Fortnight of February			Aphids per Plant
		On 100				On 100			
		Upper Leaves	Middle Leaves	Lower Leaves		Upper Leaves	Middle Leaves	Lower Leaves	
Haripal	Total number of aphids	46	65	119	101.18	7	9	31	19.49
	Aphids per leaf	0.46	0.65	1.19		0.07	0.09	0.31	
Tarakeswar	Total number of aphids	85	91	119	165.97	6	10	19	15.13
	Aphids per leaf	0.85	0.91	1.99		0.06	0.1	0.19	
Kalna	Total number of aphids	41	68	91	89.64	2	16	21	16.13
	Aphids per leaf	0.41	0.68	0.91		0.02	0.16	0.21	
Memari	Total number of aphids	9	11	25	19.59	3	10	14	11.49
	Aphids per leaf	0.09	0.11	0.25		0.03	0.1	0.14	
Burdwan	Total number of aphids	10	29	53	38.48	5	8	11	10.76
	Aphids per leaf	0.1	0.29	0.53		0.05	0.08	0.11	

TABLE 3.—*Showing the incidence of aphids per leaf and per plant during January, 1951.*

Location of Area	Aphids	First Fortnight of January			Aphids per Plant	Second Fortnight of January			Aphids per Plant
		On 100				On 100			
		Upper Leaves	Middle Leaves	Lower Leaves		Upper Leaves	Middle Leaves	Lower Leaves	
Haripal	Total number of aphids	..	5	30	15.95	4	6	20	15.90
	Aphids per leaf	..	0.05	0.3		0.04	0.06	0.2	
Tarakeswar	Total number of aphids	..	16	80	44.16	3	21	33	29.73
	Aphids per leaf	..	0.16	0.8		0.03	0.21	0.33	
Kalna	Total number of aphids	9	11	113	63.49	11	44	149	100.92
	Aphids per leaf	0.09	0.11	1.13		0.11	0.44	1.49	
Memari	Total number of aphids	6	15	50	16.76	11	17	56	44.46
	Aphids per leaf	0.06	0.15	0.5		0.11	0.17	0.56	
Burdwan	Total number of aphids	8	21	55	43.74	13	57	211	137.33
	Aphids per leaf	0.08	0.21	0.55		0.13	0.57	2.11	

TABLE 4.—*Showing the incidence of aphids per leaf and per plant during February, 1951.*

Location of Area	Aphids	First Fortnight of February			Aphids per Plant	Second Fortnight of February			Aphids per Plant
		On 100				On 100			
		Upper Leaves	Middle Leaves	Lower Leaves		Upper Leaves	Middle Leaves	Lower Leaves	
Haripal	Total number of aphids	30	60	71	94.43	90	150	234	274.02
	Aphids per leaf	0.3	0.6	0.71		0.9	1.5	2.34	
Tarakeswar	Total number of aphids	13	22	45	44.60	64	98	170	191.12
	Aphids per leaf	0.13	0.22	0.45		0.64	0.98	1.7	
Kalna	Total number of aphids	91	102	223	240.92	152	170	340	388.22
	Aphids per leaf	0.91	1.02	2.23		1.52	1.7	3.4	
Memari	Total number of aphids	131	145	336	349.56	157	172	440	436.99
	Aphids per leaf	1.31	1.45	3.36		1.57	1.72	4.4	
Burdwan	Total number of aphids	111	145	358	339.96	150	176	364	400.38
	Aphids per leaf	1.11	1.45	3.58		1.5	1.76	3.64	

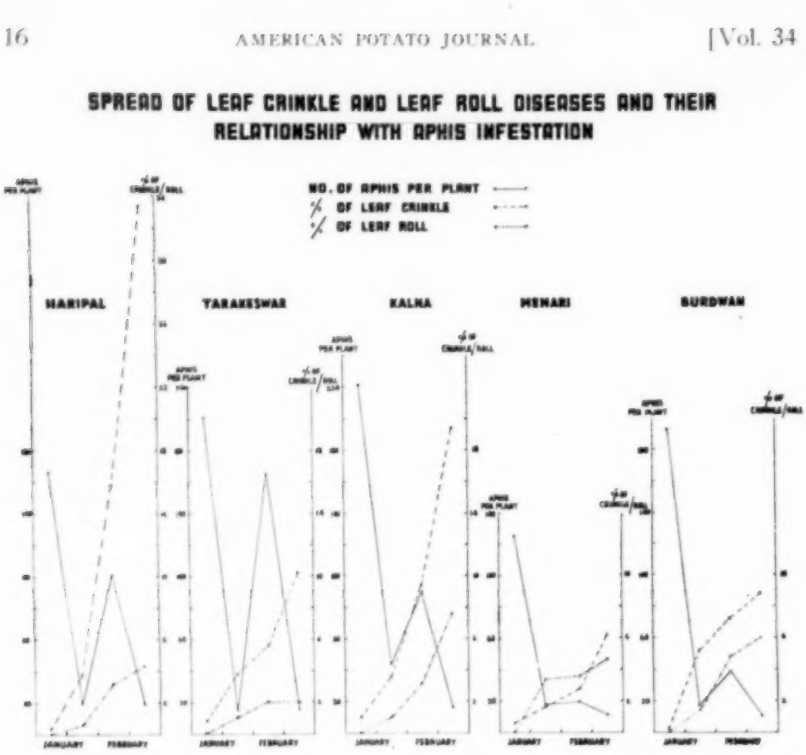

FIGURE 3.—Spread of virus diseases and their relationship with aphid infection.

TABLE 5.—*Showing the spread of crinkle and leaf roll diseases and their relationships with aphid infestation.*

Location of Area	Percentage of Infestation in Samples								Maximum Number of *Myzus persicae* per Plant
	Crinkle				Leafroll				
	January		February		January		February		
	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight	
Haripal	0.4	3.8	15.8	33.4	..	1.6	3.2	4.4	166.05
Tarakeswar	0.8	3.8	5.5	10.2	..	1.0	2.0	2.0	201.17
Kalna	1.0	3.6	9.3	19.4	..	1.0	3.2	5.6	221.68
Memari	0.6	1.6	2.8	6.2	..	3.4	3.5	4.6	125.12
Burdwan	0.2	5.1	7.1	8.8	..	1.3	4.8	6.0	192.71

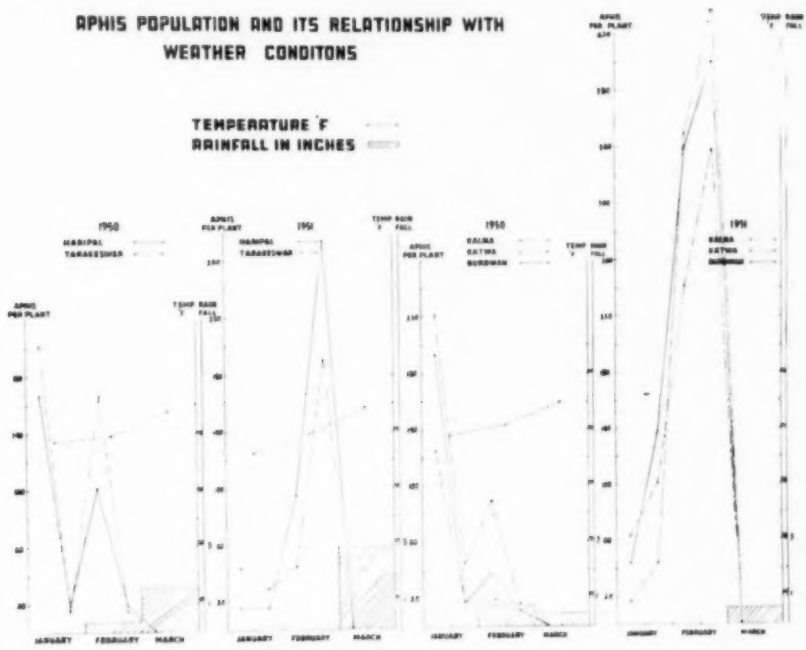

FIGURE 4.—Aphid population and its relationship with temperature and rainfall.

TABLE 6.—*Showing the comparative incidence of aphids per plant in 1950 and 1951.*

Location of Area	Aphids per Plant 1950				Aphids per Plant 1951			
	January		February		January		February	
	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight
Haripal	166.05	19.84	101.18	19.49	15.95	15.90	94.43	274.02
Tarakeswar	201.17	15.13	165.97	15.13	44.16	29.73	44.60	191.12
Kalna	221.68	44.33	89.64	16.13	63.49	100.92	240.92	388.22
Memari	125.12	18.01	19.59	11.49	16.76	44.46	349.56	436.99
	192.71	17.00	38.48	10.76	43.74	137.33	339.96	400.38

Discussion

Survey work on the incidence of aphid populations has been undertaken mainly to determine the critical aphid population above which the maintenance of healthy stocks of seed potatoes is not a practical proposition. Further, the counts of aphids throughout the period of growth of potatoes to determine the life cycle of insects, the effect of weather conditions upon them and their relation to the spread of virus diseases at different times of the season have been made by Broadbent (4) and Broadbent and Gregory (5).

Table 6 shows the comparative incidence of aphids per plant during 1950 and 1951. The observation of insect fauna twice during the month gave a more correct estimate of the number of aphids per plant during the different periods of growth of the potato crop. Bald, Norris and Helson (2) concluded that the number of aphids per plant was more a logical basis for estimating the aphid incidence than whether they had any preference for different varieties of potatoes.

It is quite apparent from table 5 and figure 4 that the migration of aphids is very much dependent on meteorological factors. Temperature and rainfall seem to have an effect on the incidence of aphids. The incidence of aphids falls with the fall of temperature and occurrence of rainfall, whereas it rises with the increase of temperature without any rainfall during the growth of the potato crop. Broadbent (4) reported similar results in North Wales, where during the dry hot summer of 1947 the aphid population increased rapidly.

Although there is no close correlation between the spread of virus diseases and the maximum number of *Myzus persicae* per plant, it was noted that there was critical aphid infestation beyond which maintenance of healthy stock of seed potatoes was a difficult problem. This point will be discussed elsewhere.

Gorham (8, 9, 10, 11 and 12) described an extensive survey conducted over a number of years in Canada. The nature of infestation was regarded as very light, light, medium or severe. According to Gorham very light infestation in Canada is apparently anything up to 10 aphids per leaf, which, however, is considered a severe infestation by Broadbent (4) in Britain.

Acknowledgment

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Summary

1. Incidence of aphids per leaf per plant during different periods of growth of the potato crop in the plains of West Bengal were studied. The number of aphids per leaf varied during the same period from year to year.

2. The fall of aphid migrations seemed to be correlated with unfavorable climatic conditions.

3. The aphids migrate from the end of December until the maturity of the crop which is at the end of February, after which the incidence falls. The intermittent fall and rise of aphid incidence is very much dependent on the meteorological factors. During February the aphids per plant varied from 10.76 to 400.38 in different centers.

4. There was no close correlation between the spread of viruses and the maximum number of aphids per plant.

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NEWS AND REVIEWS

THE POTATO INDUSTRY IN DENMARK[1]

E. KISSMEYER-NIELSEN[2]

INTRODUCTION

Denmark is situated north of Germany. The size is approximately one-third that of New York State. It is a country in which dairy farming is well developed. Denmark derives a large share of its income by export of refined dairy products; bacon, eggs and many other refined agricultural products. The climate is temperate with, generally speaking, mild winters and cool summers. The precipitation is fairly well distributed throughout the year and favorable for farming. The soil varies a great deal but a large share of it is sandy. The sandy soils are widely used for potato growing because potatoes are more profitable to grow on this type of soil than most other crops. In the following will be given a general description of the potato industry in Denmark.

GROWING

Potatoes are mainly grown on the dairy farms situated in the sandy sections of Denmark. Potatoes are one of the crops in the rotation which may be as follows: Potatoes, pasture, grain, legume and fodder beets. The land is generally flat or slightly undulating. The altitude does not exceed 500 feet anywhere.

An average and typical dairy farm is of approximately 50 acres. On a farm this size may be grown 7 or 8 acres of potatoes. There are some large farms where potatoes are grown intensively but hardly any farms where potatoes have become a specialty. There are thus very few farmers who can afford heavy mechanization of their potato operation. The potatoes are planted whole and mainly with the type of planter where the potatoes are conveyed from the hopper by means of a cup elevator. Many potatoes are planted by hand. The reason for planting the tubers whole is that the soil generally is rather moist which invites various types of infection of the seed and especially if the seed was cut in pieces as in the United States. Presprouting of the seed is widely practiced. The fertilizer is applied separately. The plant and row distances are slightly greater than in the States. Approximately 20 cwt. of seed potatoes are used per acre. Certified seed is ordinarily used at least every second year when planting for industrial potatoes or table stock potatoes. The amount of fertilizer used per acre varies greatly. One ton of fertilizer per acre is common. Manure may be used in addition. Most farms use tractors but horses are also widely used. Zinc and copper compounds are used by all potato growers for prevention of blight. Spraying is often carried out from "machine-stations" which are private or cooperatively owned, similar to the spray-rings prevalent in some sections of the United States where small acreages are grown. The insect count is fairly low in Denmark during the growing season which may account for the scarce use of insecticides. Seed potato fields are usually rogued.

[1]Accepted for publication September 20, 1956.

[2]Assistant manager, potato starch and potato granule factory, Olsted, Denmark.

Digging

Chain diggers are becoming the most common type. There are, however, still many old fashioned diggers in use. It is common practice to kill the vines by chemical or mechanical means. Digging is also often carried out by "machine-stations." There are some diggers in use that deliver the potatoes in bags or onto trucks. The picking is however mainly carried out by hand. The potatoes are picked up in various types of small containers such as baskets or crates but not in barrels and seldom in bags. The potatoes are then generally gathered into clamps in the field. Clamps are heaps of potatoes where potatoes are stored.

Storage

Most of the potatoes are stored in clamps in the field. These clamps vary greatly in size according to need and habit. A couple of hundred bushels in a clamp is, however, quite ordinary. The clamps are long, steeply sloped and fairly narrow heaps situated at ground level. Soon after termination of picking they are covered with straw and a little dirt. When winter sets in they are covered with more straw and dirt until they are judged to be safe from freezing. Drain pipes are placed in the clamp in order to provide ventilation. It is often difficult to get the potatoes sufficiently dry when putting them in clamps due to frequent rains. This may cause excessive deterioration of the potatoes due to the spread of various types of diseases. Generally speaking it is quite possible to store potatoes in clamps even through severe winters. It must be pointed out, however, that some farmers are better at constructing clamps than others.

One great disadvantage of the clamp, besides the low storage temperature, is that it is impossible to get to the potatoes in the clamp during cold spells when the dirt is frozen hard since the potatoes would freeze if the clamp is opened. This may be a hindrance for the most favorable marketing of the potatoes and is a disadvantage for the potato processor. Some modern warehouses have been built and there may be a tendency towards storing table stock and seed potatoes in warehouses. The cost of storing in modern warehouses is, however, rather high and considered too high when it comes to most potatoes for processing.

The potatoes are quite often wet when picked and are covered with a thin layer of fine humus soil. The sandy soils, where most of the potatoes are grown, contain a small amount of very dark humus which has a tendency to stick to the tubers. This is a Danish peculiarity and very disadvantageous for the reputation of Danish potatoes on the export markets. This fine dark dirt on the tubers makes it difficult to dry the potatoes in storage and thus secure a long storage life of the tubers. A great deal of work is being done in order to overcome this difficulty which also makes the grading difficult.

The storage conditions and also the cold periods result in a high sugar content of the tubers. In the starch processing it is observed that the yield of starch decreases somewhat during the winter time.

Grading

The grading is usually carried out at grading stations. These are owned by potato dealers or cooperative societies. Most of these grading

stations are modern and their equipment is similar to the equipment in an American potato warehouse. There is usually only little space for ungraded and graded potatoes. One difficulty when grading most Danish potatoes is the thin layer of fine dark humus which adheres to them and especially if they are wet, which they often are because there usually is too little time to allow the tubers to dry out before grading. Recently various types of potato washers and dryers have been used. Even when washed it is hard to make the tubers appear entirely clean and bright. A high percentage of the tubers suffer from scab due to the low acidity of the soil where the potatoes are grown. It is necessary to maintain such a low acidity for the sake of the other crops on a dairy farm. The washing shows up even slight attacks of scab and causes a high percentage of culls. These are used for starch processing or cooked for pigs but do not bring a high price.

Packing

It has not yet become general practice to pack table stock in small containers. Table stock as well as seed potatoes are generally packed in 110 pound burlap bags. A few potato dealers selling on the home market have recently begun packing in smaller paper bags. This practice is only in its infancy but may very well develop due to the increasing number of self service grocery stores in Denmark

Generally speaking the packing of potatoes has not become as well developed as in the States.

Inspection

The inspections of the seed potatoes are carried out by the government. This inspection is very thorough and is carried out in the field as well as in the grading station. The bags of seed potatoes are sealed by the inspectors. Also table stock for export is inspected but table stock for the home market is not.

Quality

A great deal of work is done to secure a good quality seed potato a large share of which is exported, mainly to European, Central and South American countries. One great disadvantage is the dark appearance due to the thin coating of dark humus. Holland is Denmark's most severe competitor on the export market of both seed and table potatoes. The Dutch potatoes are mainly grown on a silty loam which leaves the tubers bright and clean in appearance. This, together with various other factors, has caused the Danish potato exports to decline while the Dutch have been gaining or kept their ground. Among the other factors are, that Danish seed potatoes, especially the variety Alpha, when planted in southern European countries have a tendency to uneven growth. There may be a great many reasons for this behavior but one of the reasons may very well be the lack of controlled storage conditions. In Holland most of the potatoes are stored in warehouses under controlled conditions.

Danish seed potatoes, however, have been bought in large quantities in many foreign countries for many consecutive years with satisfactory results.

As far as the table stock goes Denmark grows entirely different types of potatoes than are grown in the States. On the home market table potatoes are consumed mainly as whole cooked or scalloped potatoes. The Danish people eat very few mashed potatoes, french fries, baked potatoes, chips or sticks. The most common eating potato is Bintje, which is rather low in dry matter, namely about 18 per cent. It is a somewhat waxy potato and has a nice flavor. It can be used for mashed potatoes but does not yield a mash which would satisfy American eating habits. The sugar content of table stock has not yet been considered an important factor for the eating quality. This is probably a fault because table stock with a low sugar content is of better eating quality than table stock with a high sugar content. Specific gravity grading of table stock is unknown in Denmark.

Still Danish table stock is good for ordinary cooked or escalloped potatoes. Many countries import large quantities of Danish table stock year after year.

Potato Breeding and Research

Extensive work in order to develop new potato varieties is carried out at Vandel Potato Breeding Station. Also investigations of virus diseases are carried out at this station and various agricultural research stations. Problems connected with potato storing also are being investigated at various research stations.

Marketing

Export of potatoes is mainly organized by one society, a central organization of most of the exporters. This tends to stabilize the price. This organization owns large modern warehouses at two of the main export ports. Here potatoes, ready for export, are gathered and loaded into ships. The potatoes are here reinspected by government inspectors and any lots that are turned down may be regraded.

The marketing of potatoes on the home market is not centralized but carried out by a large number of small dealers.

Statistics

Table 1.—*Potato acreage, in hectares**

Year	Islands	Mainland	Total	Tons of Potatoes per Hectare*
1953	14,669	92,107	106,776	17.7
1954	13,883	82,998	96,881	20.0
1955	13,500	79,800	93,300	15.4

*1 hectare = approximately 2½ acres.

TABLE 2.—*Utilization of the potato harvest.*

	1000 tons Season (September 1—August 31)		
	1954/55	1953/54	1952/53
Harvest minus waste	1744	1690	2082
Import minus export	–48	–119	–199
For disposal	1696	1571	1883
Seed potatoes	222	242	270
Used for processing	142	169	225
" " table stock	530	525	520
" " fodder (animal feed)	802	635	868

TABLE 3.—*Potato export.*

1954	1955
49,050 tons	25,788 tons
value, kr.* 12,000,000	7,000,000
$1,700,000	$1,000,000

*7 kr. equals approximately $1.00

TABLE 4.—*Cost, average per hectare.**

	1952-53	1953-54
Number of accounts used	57	45
Crop in hkg. (one hkg app. 2.2 cwt.)	230.3	220.2
Value of crop in kr. (one kr. = approx. 14¢)	2,967	2,757
" " " " dollars per acre (approx.)	170	158
Production cost, kr.:		
Special costs:		
Seed potatoes	416	414
Fertilizer	289	275
Labor	1,014	969
Horsepower	220	183
Tractor and rent of machines	127	162
Other equipment	186	185
Freight, Spraying, etc.	41	73
Special costs total	2,293	2,261
" " kr. hkg.	9.96	10.27
" " dollars per acre	131	125
Ordinary Expenses:		
Manager	192	207
Buildings	29	38
Interest	94	95
Taxes	49	50
Conservation	17	13
Etc.	34	34
Ordinary expenses, total	415	437
" " dollars per acre	24	25
Production cost, total	2,708	2,698
" " per hkg.	11.76	12.25
" " dollars per acre	155	150
Net-profits, kr.	259	59
The crop sold for kr. per hkg.		12.52

*1 hectare = approximately 2½ acres.

Processing of Potatoes

Potatoes are mainly processed for starch and its derivatives, alcohol and recently potato granules. There are seven starch factories, each processing from 15,000 to 25,000 tons of potatoes a year. One of these starch factories produces starch granules for special types of soup and another starch factory also produces potato granules. A large share of the starch is used for glucose and dextrose. Some years there is a considerable export of potato starch to South America and U.S.A. The production of alcohol from potatoes is decreasing partly because sugar beets are used as raw material instead and partly because alcohol as a by-product from oil refineries is coming into the picture.

There is some production of potato chips and sticks but it does not seem to get a firm grasp on the market. It is difficult to produce these products in Denmark due to the high sugar content of the tubers.

Summary

Denmark grows a considerale amount of potatoes. The potatoes are grown on medium sized or small dairy farms in the sandy parts of Denmark where potato growing is more profitable than growing of most other crops. The Danish climate is, generally speaking, well adapted to potato growing. Two distinct types of potatoes are grown, namely table potatoes and industrial potatoes.

Denmark usually exports large amounts of seed and table potatoes. One disadvantage is a thin coating on the tubers of a fine dark humus which is hard to get off.

Large amounts of potatoes are used for processing, mainly starch, but also for alcohol, potato granules, chips and sticks.

HIGHLIGHTS OF A HALF-CENTURY IN POTATO PRODUCTION[1]

Arthur Hawkins[2]

At the turn of the century, U. S. potato acreage totaled about three million. It increased to four million during World War I, then fell off to 2.8 million by 1939. In 1955, potatoes were harvested from only a little over 1.4 million acres.

In the same period of time, the average potato yield rose from just under 100 bushels per acre in 1900 to about 140 bushels in the early 1940's, jumped to 253 during 1945-1950, and reached the record high of 267 bushels per acre in 1955..

Production averaged 361 million bushels during 1939-1942, and soared to 428 million in the price support years of 1943-1950. Since then, without benefit of price support, production averaged 361 million bushels during 1951-1954, and the 1955 crop was estimated at 378 million.

[1]Reprinted, with permission, from Market Growers Journal, September 1956.
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Thanks to the great rise in yield per acre, annual volume of potatoes has remained at a high level for the past 17 years in spite of sharply reduced acreage. Several factors account for the larger yields, including reduction of low-yielding acreage; concentrated production on specialized potato farms; new varieties, increased use of certified seed; improved cultural practices (especially more efficient insect and disease control) and the increased use of irrigation.

Geographical Shifts

In the early 1900's, potato acreage was centered primarily in New York, Michigan, Wisconsin, Minnesota, Maine, and Pennsylvania. Considerable acreage was also grown in the corn belt states. (Figure 1)

The 1949 Census map (Figure 2) shows the importance of potato production in the West, and a marked reduction of acreage in the corn belt states and western New York. Production is parts of Maine, Idaho, California, on Long Island, in the Red River Valley of Minnesota and North Dakota, and Colorado.

With the shift from low-yielding and non-commercial acreage, a greater part of the crop is now grown on soils more suitable for potatoes, in larger enterprises and in specialized areas. Potato production has shifted into the high-yielding states. The westward movement continues in 1956, with further acreage increases in Idaho.

Fewer and Bigger Farms

During the past 15 years in particular, there has been a trend toward fewer farms growing the crop, but with a larger acreage per farm. Much of the acreage decrease after the war was brought about by elimination of marginal acreage, and by a tendency to discontinue growing potatoes for farm use only.

Between 1944 and 1949 the number of farms producing potatoes dropped 21 per cent, from about two million to 1.65 million bushels. The 1949 Census shows 82 per cent of the crop produced on about 31,000 farms that grew ten acres or more. The 13,000 farmers who grew 25 acres or more produced 63 per cent of the crop.

New Methods

Specialization, aided by the research scientist and the agricultural engineer, has brought changes in methods of potato production. Along with mechanical equipment for large scale production these methods have changed the pattern of yesteryear.

One of the most important reasons for higher yield is the development of more effective spray materials to control insects and diseases. DDT, which came into use as an insecticide in 1946, and the more recent organic phosphate compounds are entitled to a good share of the honors.

Fertilization rates have increased, especially in the East. Seed is closer spaced. Much of the acreage in humid producing areas is now provided with irrigation.

FIGURE 1.—Irish potatoes—Acreage, 1899.

FIGURE 2.—Irish potatoes—Acreage, 1949.

VARIETIES

Until about 20 years ago, potato varieties most commonly grown for the late crop belonged to the Green Mountain and Rural groups while Irish Cobbler, Triumph, and Spaulding Rose were grown for the early crop.

Many new varieties have been distributed under the National Potato Breeding Program since its organization in 1929. Katahdin, the first of these, appeared in 1932 and now holds first place in certified seed acreage among all varieties grown in the U. S. Its popularity is due to wide adaption, resistance to diseases, immunity to net necrosis, and desirable shape.

Green Mountain has been largely displaced by this and other new varieties. In addition to Katahdin and Cobbler, important varieties now grown include Red Pontiac, White Rose, Russet Burbank, Kennebec, Chippewa, Cherokee, Sebago and Red McClure.

Mechanization

Commercial potato farmers today are mechanized to the extent that horse-drawn equipment is almost a rarity. Two- and four-row planters and automatic seed cutters are a far cry from hand operations. More recent methods include filling potato planters with seed and fertilizer by means of conveyor belts from bulk boxes.

Sprayers with booms wide enough to cover 12 or more rows thoroughly on each trip across the field are common, in contrast to the old hand-pump machines of earlier days.

Harvesting has changed from hand implements and the horse-drawn traction digger to engine-powered two-row diggers. The most recent change in mechanization of potato production is the use of mechanical potato harvesters. These have been used for several years in the Red River Valley, where over 80 per cent of the acreage is harvested with either direct or indirect harvesters. Commercially built two-row harvesters were not used in Maine until 1955.

A crew of 10 to 15, using mechanical harvesters and equipment for handling potatoes in bulk trucks from field to storage, can harvest, haul and store 2,000-5,000 bushels in an eight-hour work day. The job no longer requires heavy labor.

Modern storages have floor flues and thermostatically-controlled forced ventilation and air circulation systems using air proportioning. There is much interest in storage of potatoes in palletized boxes holding about 30 bushels. Mechanical bin unloaders and sluice-ways are new methods of conveying potatoes from storage to washers or graders.

Marketing

Per capita consumption of potatoes, based on disappearance of the crop, declined from 154 lbs. in the 1910-1919 period to 128 lbs. in 1935-1939. It slipped to 100 lbs. per person per year in 1951-1955. However, the downward trend seems to have been stabilized during the past few years, mainly because of increased use of potatoes in processed form.

USDA Marketing Service reports that while the level of production is about the same as it was 15 years ago, the quantity sold is larger, averaging 307 million bushels in 1950-1954 compared with 262 million in 1939-1943. The larger quantities now sold find their way increasingly into new outlets.

Many potatoes are used for potato chips, frozen French fries, in soups, dehydration, and other processed forms. Excluding quantities used as food on farms where grown, and quantities sold to restaurants, hotels, and institutions—potatoes purchased by consumers for use in fresh form in the home are estimated at less than half the crop sold for food.

It is reported that about 54 million bushels of the 1955 crop were bought by processors. Thus, one bushel out of every five was sold for food by growers for processing, compared with one out of 50 in 1940. Of the potatoes sold for processing last year, about 75 per cent were used for chipping and about 10 per cent for frozen French fries and other frozen prepared products. Processors prefer and demand potatoes high in solid matter content for potato chips and frozen prepared products.

Potatoes in fresh form are being more extensively sold in consumer-sized packages. Estimates are that about 25 per cent of potatoes sold for food is now packaged. This has brought more attention to cleaning potatoes by brushing or washing, and packaging within a closer size range.

Prepeeling of potatoes is increasingly important. An estimated 150 prepeelers in the U. S. now prepare about three million bushels annually for restaurants and hotels.

Continued progress in the processing of potatoes and in the per capita consumption of processed potatoes is expected. More and better services in washing, packaging, and sizing—and better quality, both internal and external—will help check the decline in per capita consumption of potatoes in the fresh form.

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